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DESIGN AND DEVELOPMENT OF NATURAL HAND GLOVES,(U)
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Quartermaster Research & Engineering Center

Natick, Massachusetts

CLOTHING & ORGANIC MATERIALS DIVISION

Clothing & Equipment Development Branch
Series Report No. 33

DESIGN AND DEVELOPMENT OF NATURAL HAND GLOVES

by

Dr. Stephen J. Kennedy,
Robert L. Woodbury and Herman Madnick

162842

Approved: Theodore L. Bailey
Chief, Clothing & Equipment Development Branch

Project Reference:
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DESIGN AND DEVELOPMENT OF NATURAL HAND GLOVES

I. Introduction

Historians have stated that the use of gloves is of high antiquity and apparently was known even to prehistoric cave dwellers. Statements of this sort, which appear all through the literature on history of handwear, are apparently based upon analogies to the Eskimo in the Paleolithic culture. In all probability the various groups of upper Paleolithic peoples in Europe and other regions of the Holarctic Zones used some sort of hand covering, however, there is absolutely no evidence that such was the case. Such perishable materials as would have had to be employed would not have withstood the ravages of time.

A sophisticated continuous fourchette glove was found in the tomb of Tutankhamen (18th Dynasty, 14th Century, B.C.). King Tut's glove belongs to the lineage of the dress glove associated with ceremonial occasions and symbolizing the social gulf between the nobility and the Fellaheen. The earliest concrete evidence bearing on some form of occupational or work hand covering came to light in the Hallstatt (Early Iron Age) Salt Mines of Lower Austria. These mines were exploited during the early part of the first millennium B.C. (Circa 800-650 B.C.). This information was obtained from Professor H. L. Movius, of Harvard University, Abri Patand, Les Eyzies (Dordogne) France, 11 August 1960.

In modern times, with the increasing use of heavy machinery and tools, the use of gloves for protecting the hands of workers has constituted a major area of development. For the most part, two factors have dominated design of such gloves: durability (ruggedness or serviceability) and price.

Durable construction and low cost production characterize present day work gloves above all else. Gloves having special construction features, such as gauntlets, extra reinforcing patches, reinforcement with metal-bearing abrasion-resistant surfaces, and special acid-resistant or other similar special types of materials, dominate the work glove field.

The concept of function of this handwear, maximizing what the man can do when wearing this glove, is clearly given third place if it is considered at all. The point is that workers will not pay very much for a glove, and hence, it must be cheap and durable; whether he can bend his fingers while wearing the glove, or whether his hands become fatigued from "working against" the glove, appear to receive little consideration in work glove design.

From the standpoint of military handwear, however, this matter of the man's being able to perform his assigned tasks with dexterity and over

absence of fatigue, is our primary consideration. Soldiers are sent to the battlefield not to demonstrate durability on their clothing items, or the low cost of the items, any more than to show off the appearance of their items of clothing. They are there to perform certain tasks and the efficiency with which they perform these tasks will determine whether they or their opponents win, and more important, whether our nation may be able to survive.

Hence, the handwear of the soldier, which determines the degree of skill with which he can perform many of his most critical battlefield tasks, constitutes one of the most important areas for research and development to increase the efficiency of the combat soldier.

II. Approaches to Functional Design

Handwear, like other elements of the soldiers' equipment, bears a definite relationship to the natural and enemy-imposed environments in which the soldier finds himself. His handwear must provide insulation against the cold; protection against rain and snow (without getting wet); and it must be able to stand up reasonably well against the physical elements, i.e., the abrasive surfaces of what he handles, the muck, ooze, wet snow or mud into which his hands are forced. It must also evoke no important psychological or physiological performance decrements. The man must not feel that his gloves are "in the way" so that he must remove them to get his job done, and they must not unduly fatigue his hands and forearm muscles.

It is these last factors of reduction of fatigue and the obtrusiveness of the handwear in performing a task which are peculiarly critical in military handwear, and which are also passed over lightly or largely ignored in civilian handwear. In the Quartermaster Research and Development Program on Handwear, this has constituted an area of study and experimental design.

This objective of prevention of fatigue of the hands, which can be caused by the handwear, can be dealt with in at least three ways: (a) by use of stretch type materials; (b) by use of special patterns that do not bind the movement of the fingers or the hand; and (c) by building into the glove a shape which corresponds to the natural hand.

III. The Use of Stretch Type Materials

As in many areas of clothing where origins are lost in the ruins of antiquity, the concept of suitable types of materials for gloves was worked out so long ago we tend to take the availability of such materials for granted today.

Who would consider there to be anything revolutionary about using a tight-knitted material for gloves? In part, this is so taken for granted and not ever given second thought, that our country is willing to let

our knitted glove industry be liquidated through allowing imports from abroad to force domestic producers out of business. Actually, our knitted wool gloves are an excellent material for an insulating insert in a leather glove and for which no equally efficient substitute has yet been produced.

Or who would think of leather as a radical type of material for gloves? Yet, over the centuries, as a prime example of artisanship and craftsmanship, special types of glove leathers have been produced that have the desired characteristics of a second skin.

From a military standpoint, the chief difficulty with leather for gloves and leather gloves is that in peacetime these materials are used for appearance primarily. Hence, the gloves take on characteristics which may be and actually are often opposed to the proper concept of military functional gloves.

Why do we need stretch in glove materials? The answer to that is found in the changes in dimension of the hand which occur in normal use, which must be accommodated by the glove material if the hand is not to be unduly constricted. For example, the length of the back of the hand increases by almost an inch in the simple process of bending and flexing the hand(1). The palmar side of the hand, similarly, is shortened substantially; this amount, to around 5/8 inch. The problem of the glove designer is what to do with the material on the palm side of the hand which is not needed when the hand is flexed and where to get that extra inch of length on the back of the hand. Part of this can be obtained from stretching of the material itself. The surplus material on the palm can be dealt with only by careful designing to shorten the palm of the glove or to obtain a curved finger glove. This is easily said but the difficulties of actual construction are certainly not small, as all glove designers appreciate.

Similarly, there is the problem of width and girth changes in the hand(1). When the fingers are extended, the girth of a typical hand might be 7-1/2 inches but when the hand is closed, it will be an inch larger. Again, the problem is where to get this extra material.

The advantages of a knitted material as providing two-way stretch at low energy levels will be evident. A knitted construction easily stretches within any direction and avoids any serious limitation on the bending of the hand or any significant muscular effort to bend the fingers.

Similarly, stretch can be built into leather. Going back almost into antiquity, glove makers and designs have learned how to treat skins of many animals, so as to retain stretch in the natural leather. The careful control of stretch in the leather, both in the tanning and in the cutting, is actually the secret of high priced leather gloves.

Commercial types of dress gloves, however, even though made from leathers having desirable stretch characteristics, tend to be made so tight fitting that even though the stretch in the leather is there and can be used for bending the fingers, considerable effort is required, fatigue develops, and blood flow is constricted.

IV. Special Patterns That Do Not Bind the Fingers or Hand

A significant achievement of the Quartermaster Corps, development of its glove shell leather, for example, has been the design of patterns which when properly fitted have enough space provided around the fingers and hands so that even when the glove insert is used for providing warmth, there is enough room in the glove to enable the hand to bend without any feeling of serious constriction. This is achieved in part by the manner in which the patterns are designed and also by employment of the principle that excess material can be drawn to the back of the hands by the use of a strap just above the wrist which draws surplus material away from the palmar surface to the back of the hand. In this way, extra dimensions have been worked into each pattern element without broadening the working surface of the glove unduly with extra material.

One factor of this approach is to insure that the glove finger length is calibrated to that of the shortest fingered hands so that the tips of the wearer's fingers will always be at the finger tips of the gloves, with sufficient dimensions elsewhere to accommodate extra long fingered hands.

Important as this approach is, however, it does not reduce sufficiently the fatigue resulting from the bending of the fingers to perform any essential tasks. In order to make it possible, the surplus material must be removed from the palmar surface when the hand is in a "natural" position, and a corresponding increase must take place in the length of the back and in the girth at the same time.

V. Building into the Glove a Shape Which Corresponds to the Natural Hand

A great deal of effort has been expended in attempting to develop curved palm gloves or mittens. The first partially successful accomplishment in this direction was the development of the Arctic Mitten by Mr. Donald Huxley of the U.S. Air Force Clothing Branch which later was adopted by the Army.

In this accomplishment, a modicum of curvature was introduced by tensioning the outer edge of the palmar surface by the use of a bias cut and fitted piece as the outer edge of the palm. This approach was in apposition to the moccasining of the palmar surface leather where it is joined to the back of the mitten. It was a significant accomplishment but did not lend itself to the achievement of a glove design.

Following the conference on "Protection and Function of the Hands in Cold Climates" held at the Quartermaster Research & Engineering Command, Natick, Massachusetts, 23 and 24 April 1956(1), at which the importance of this problem was stressed, a new approach was taken by technologists at this Command to work out an improved finger and palm glove in a dipped type construction. This has been eminently successful and some of the principles developed in its accomplishment have not yet been extended to the patterning of leather gloves.

VI. The Development of a Synthetic Hand

Through the efforts of the Department of Labor, an appreciable degree of commercial standardization of sizing and size designation was achieved in the late 1930's in men's, women's, and children's body clothing. Up to the present, no such standardization has been accomplished in the field of handwear.

In the manufacture of commercial handwear (supported, unsupported, fabric, or leather) each glove designer has utilized his own concept of fit, and as a result, no two manufacturers provide precisely the same inside measurements for the same type of glove, but make a variety of sizes in one style in order for the purchaser to have a choice as to which size is suited for his specific purpose.

The present canton-flanneled, vinyl-coated, protective handwear for missile fuel and oxidizer handlers consist of commercial large gauntlet-type gloves which are generally unsatisfactory for use due to poor fit and design. Since these gloves, for Government use, are purchased from the lowest bidder when they are procured, the quantities received may not be of the same size as others already in stock but may vary from manufacturer to manufacturer. Thus, the missile-man who wears these gloves may receive a pair providing a fair fit one time, and as a replacement, may receive a very unsatisfactory fitting pair. The man with a poor fitting glove is at a disadvantage and often cannot accomplish his required tasks efficiently and safely.

With the advent of more highly toxic and dangerous materials for use as missile propellants, the requirement arose for a glove having both a good fit and an impermeable gauntlet sleeve juncture, which can provide standardized fit, better dexterity and less interferance with skilled manipulation than the usual canton-flannel vinyl-coated handwear no matter which manufacturer is the successful bidder.

Since the measurements and fit of supported and unsupported handwear is controlled by the dipping forms, development of anthropometrically derived reference hand forms was undertaken to provide a basis for master model dipping forms.

a. <u>Initial Experiments</u>

Work done in 1956 under contract to the Quartermaster Research & Engineering Command by Dr. John Lyman of the Department of Engineering of UCLA(2) confirmed the criticalness of fit at the fingertips that had been recognized intuitively during the development of the U.S. Army Glove, Shell, Leather, during World War II. In an effort to apply these findings as well as to initiate the design of the basic anthropometric hand forms, three sizes were picked as a starting point. For the reference hand forms, the small size is based on the broadest and thickest measurements of the 30th percentile population level, the medium on the 75th and the large on the 95th percentile. To insure short finger lengths, the small size is based on the 5th percent level, the medium on the 31st, and the large on the 76th percentile.

Since the Air Force had completed several detailed studies of hands(3), and the anthropologists of the Quartermaster Research & Engineering Command had completed but not published a general manumetric survey and had a study of the relaxed hand underway, it was decided that measurements from both sources could be utilized in designing the basic hand forms. The standard measurements taken by anthropometrists are made with the hands in an unnaturally flat position which makes it easier to get consistent results. These data were not usable directly for the design of the hand form, thus, the dimensions actually employed were corrected for a natural rest or ready-for-work pose by recording the differences in finger lengths, etc., using data from a dozen widely varying pairs of hands measured in both positions. It was found that the differences for each measurement were quite consistent regardless of hand size or type.

It was considered that handwear should be designed around the basic types of prehension, as defined by Schlesinger(4). (See Figure 1)

The dimensions derived from the manumetric studies (Tables I through XI) previously mentioned were utilized as the basic measurements for the master model hand forms. These measurements were converted to three-dimensions by application of the skill of a recognized professional sculptor, Mrs. Elizabeth McLean-Smith of Boston, Massachusetts, under contract to the Government. It was assumed that with available anthropometric data and a sculptor's artistry, forms for glove design could be developed which would result in a great improvement in handwear fit.

b. <u>Fabrication of Master Model Hands</u>

To make the master model hands of the type and quality required, the Institute of Contemporary Arts was requested to suggest sculptors capable of producing model hands based on anthropometric data. The artist selected had previous experience in converting abstract numbers into

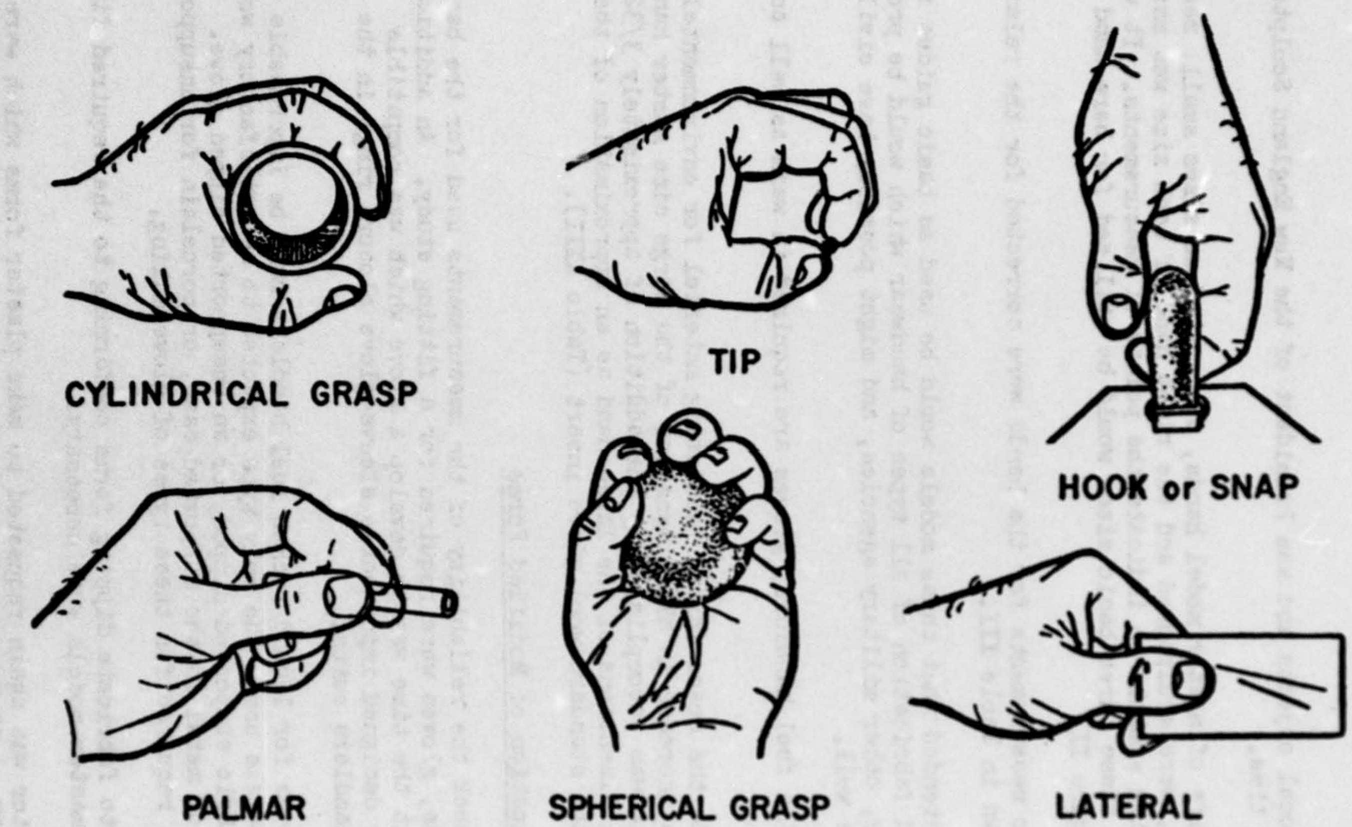

Figure 1. Six Basic Types of Prehension, as defined by Schlesinger Reprinted from "Artificial Limbs" May 1955

three dimensional objects and was President of the New England Sculptor's Guild at that time.

Three pairs of master model hands, designated as sizes small, medium, and large, were sculptured and the right hand of each size was marked with identifying symbols to indicate the points of measurements. It was intended that these three basic sizes would be utilized for bare-hand fit. (See Figure II)

The basic measurements for the hands were corrected for the relaxed shape, as shown in Table XII.

It was intended that these models would be used as basic guides for the design and fabrication of all types of handwear which would be procured for Army, other military agencies, and might possibly have civilian application as well.

For missile fuel handlers, gloves are required in warm as well as cold weather.

To provide the space for an insulating material for environmental protection, an increase in all dimensions of the large size master hand was made. This was accomplished by the addition of approximately 3/32" to the initial dimensions of the large hand as an approximation of the thickness of the standard wool glove insert (Table XIII).

c. Fabrication of Modified Forms

To check the reliability of the measurements used for the basic reference hands, gloves were required for a fitting study. An additional objective at the time was to develop a glove which was compatible with the newly designed impermeable sleeve-glove closure rings in the missile fuel handlers suits.

Since gloves for liquid rocket fuel handlers must be impermeable to the toxic materials used, the only type expected to be satisfactory would be either a fabric supported dipped, or an unsupported dipped glove. Dipping forms of metal in the supported case, or porcelain for unsupported gloves, are required for these types of glove making.

In order to fabricate dipping forms conforming to the required fitting concept, master models were necessary.

The sculptor was again requested to make plaster forms which were designated as "Type B" Forms. These include for the gauntlet, the inside dimensions of the cone shaped glove closure ring and increased dimensions in the wrist area for ease in donning and doffing. The dimensions for the wrist circumference was established by measuring the hand girth of personnel within each range group at the knuckles with the fingers con-

Figure 2. Master Model Hands - Side View

verging and the thumb displaced to lie as close to the palm as possible (Figure 3). Those measurements utilized are as follows: size small, 9-1/8"; size medium, 9-3/4"; size large, 10-1/4"; and size extra large, 10-3/4". The hand portion was to remain identical to the master model hands. For Government application, to be compatible with the missile fuel handlers suit, the total length of the gloves from the tip of the curved finger to the top of the ring was determined to be: size small, 12-1/2"; size medium, 13"; size large, 13-1/2"; and for size extra large, 14". An additional two inches was allowed for trimming.

All "Type B" plaster forms, and the dipping forms based on them, are of the same dimensions.

d. Fabrication of Metal Dipping Forms

Various glove dipping companies were solicited in an effort to find a company willing and able to duplicate the Plaster of Paris "Type B" forms in aluminum.

This metal was chosen since many supported glove dipping companies utilize aluminum production forms.

In addition, it was felt that if the resulting gloves were not satisfactory with regard to fit, or if they could not be successfully dipped due to design, the aluminum forms could be modified directly rather than repeating the entire process.

An integral thumb was used since the fabric utilized as the base material was interlock knit, which, due to its elasticity, is easy to last onto the dipping forms.

The original production dipping forms were manufactured by sand casting. The gauntlet area was hollow, but fingers and thumb solid (Figure 4).

All rough areas of the aluminum castings were smoothed off so that a fabric could be lasted without damage.

On inspection of the finished aluminum forms, all critical measurements were satisfactory.

e. Fabrication of Experimental Gloves

A unique two-piece patterned fabric liner was developed and lasted on the experimental hand form as footwear patterns are designed for the last. To make the experimental gloves, normal quality prototype production procedure was followed. The dipping forms, one at a time, were slowly immersed in the dipping compound, ensuring that the tips of the fingers en-

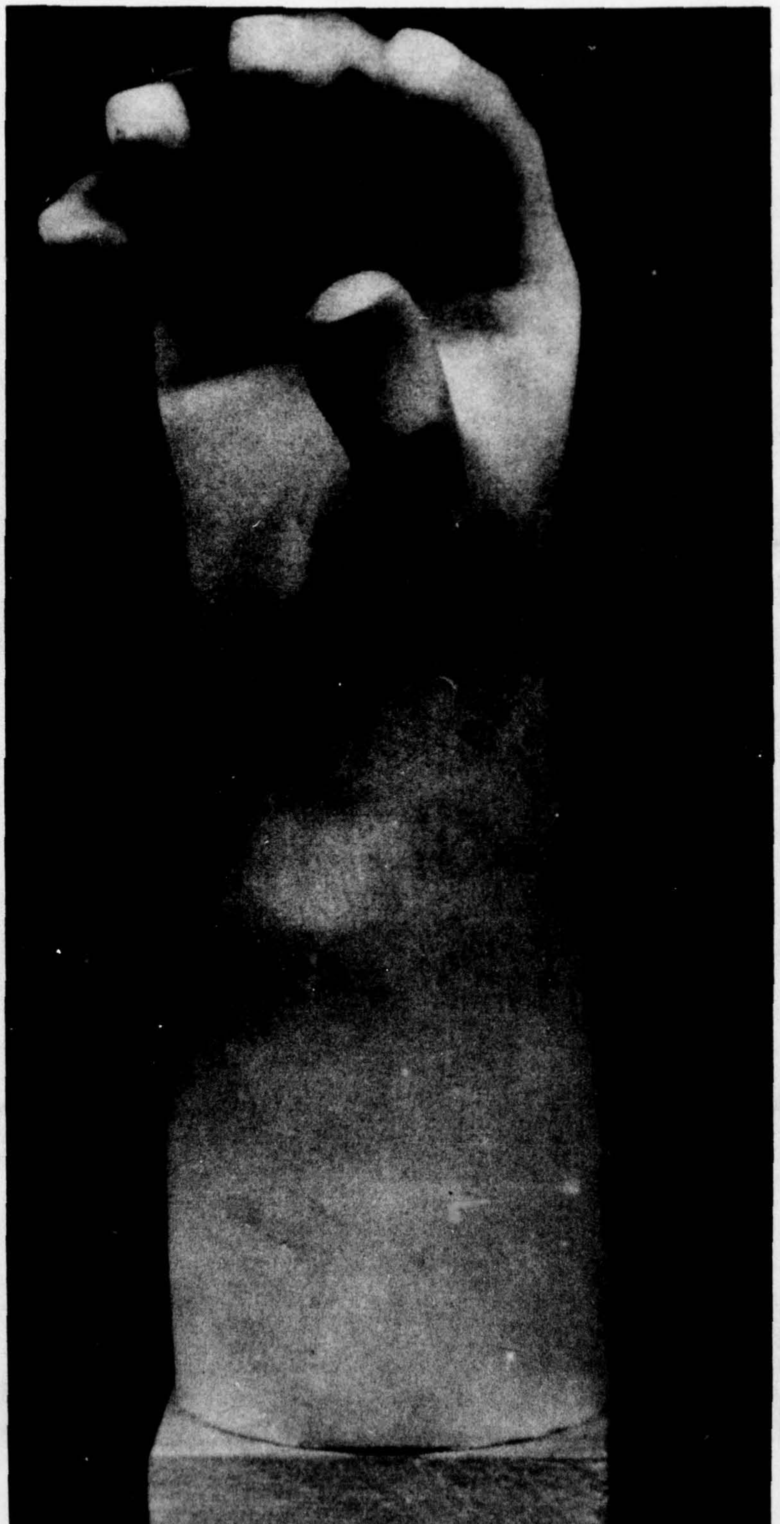

Figure 3. Type B Plaster Form

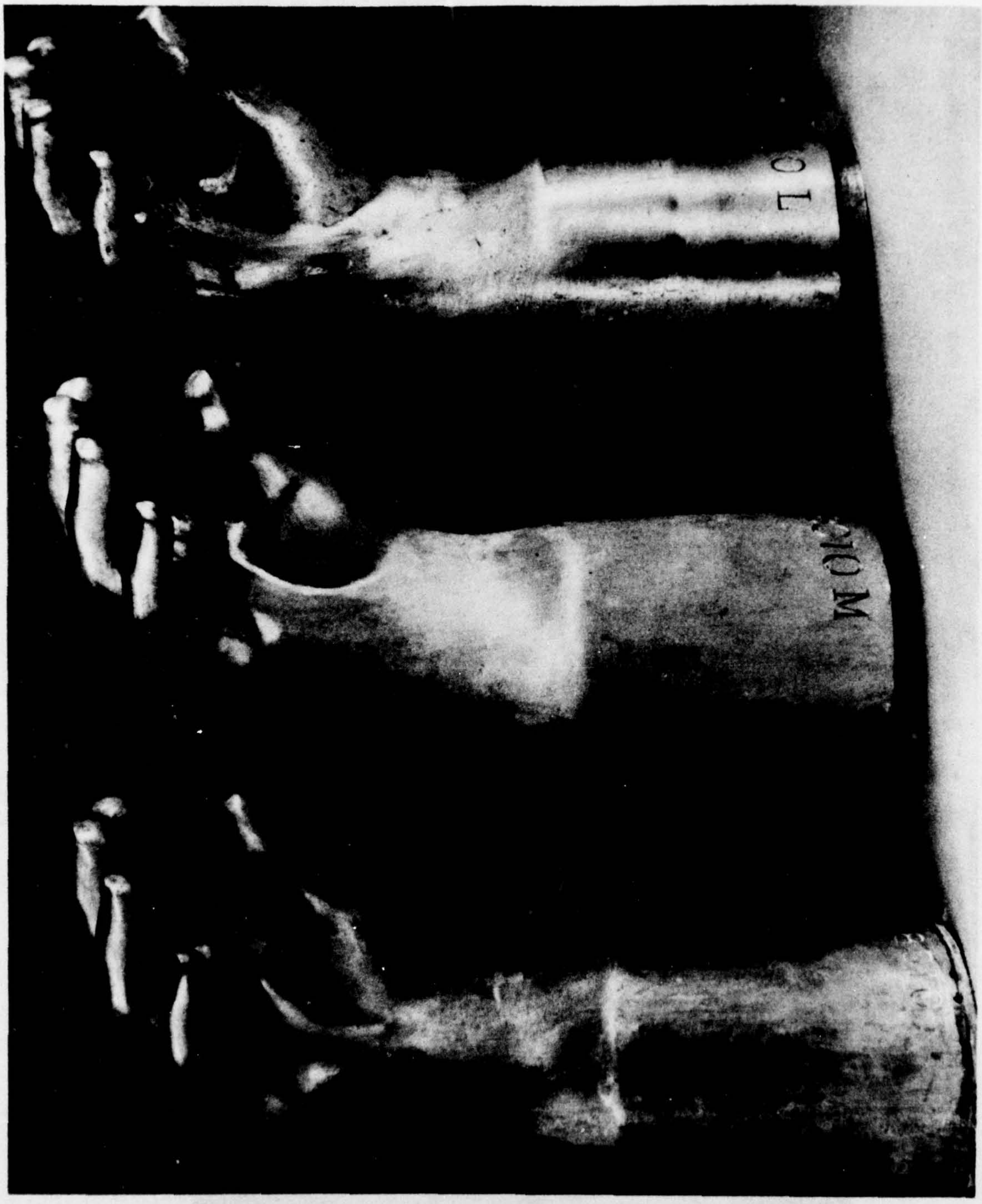

Figure 4. Aluminum Dipping Forms

tered the solution first, and slowly covering the hand so that no air bubbles would accumulate on the surface. Withdrawal was accomplished slowly in an arc so that the finger tips were removed last. To remove excessive dipping compound and to eliminate webbing at the finger crotches, forms were suspended at an angle, so that the finger tips were in the lowest position. For the gloves made (Figure 5), and for the consistency of the solution used, the dripping time lasted from ten to fifteen minutes, after which time they were turned right side up to allow the accumulated material at the finger tips to run back.

In order to create a gripping surface, the forms were again immersed in a compound which contained unplasticized particles of powdered vinyl resin, following the same procedure as for the basic dip, except more rapidly and only up to the heel of the palm.

VII. <u>Sizing Study</u>

a. <u>Method</u>

In order to evaluate the design of the forms, a fitting and sizing study was conducted(5).

The Study consisted of trial fittings of the test gloves with and without the use of the standard wool glove inserts worn underneath. A sample of 285 test subjects was utilized. Twenty-one anthropometric hand dimensions were obtained on all subjects and item size and quality of fit were recorded.

Information on ability to don and doff the glove was obtained on 102 of these subjects. The subjects were processed in turn through the anthropometric measurements; the vinyl glove over the base hand; the vinyl glove over the wool insert; and ease of donning and doffing was recorded.

b. <u>Conclusion</u>

The fitting phase of the experimental gloves indicated that a high percentage of the male military population can be expected to be properly fitted with the four sizes provided. The high percentage of "good fits" and the comments of the test subjects were indicative of a well designed glove.

A tariff for this glove based on the bare hand dimensions of gloves would be as follows: 22% small, 57% medium, 16% large, and 5% extra large. Since over half of the study sample required a larger glove when the wool insert was worn, the size tariff listed above would not be applicable if wool inserts were worn. In such a case, the estimated tariff would be: 5% small, 35% medium, 51% large, and 9% extra large.

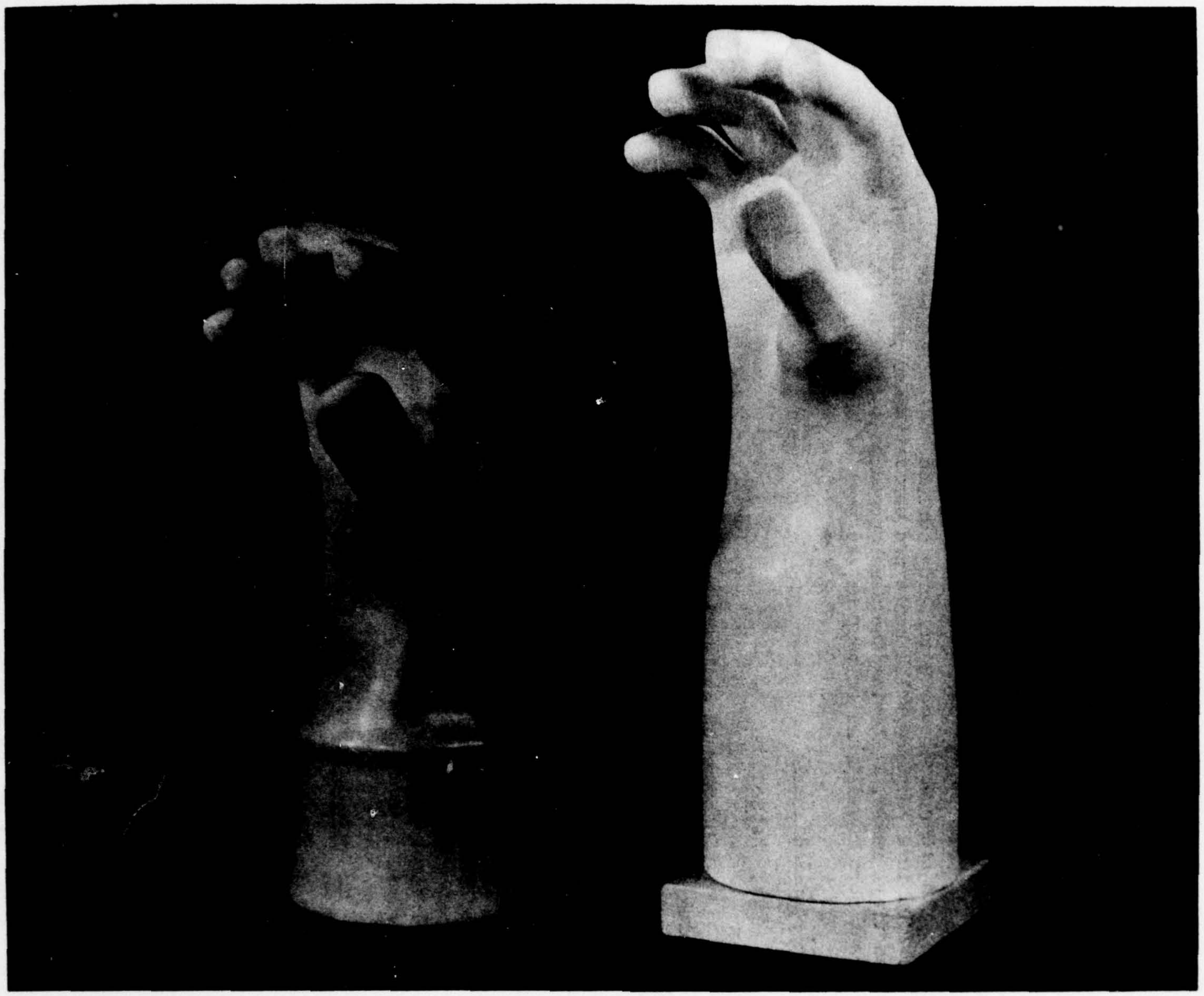

Figure 5. Finished Anthropometric Glove v/s Type B Form

VIII. Fabrication of Porcelain Dipping Forms

There are two porcelain manufacturing companies which are known to be suppliers of hand dipping forms to the rubber glove dipping industry. Contracts were negotiated with both of these manufacturing companies for the fabrication of small quantities of dipping forms in all four sizes and to fabricate blocks and casings in order to insure that dipping forms of the Government design are available for purchase for either Government or commercial applications.

Early in the fabrication of the dipping forms for Government use, it was found that the fingers drooped during firing in the kiln. This was corrected by the use of a wedge in the front of the green form to tip back the hand. Once this was corrected, there were no problems in firing and obtaining the desired shape and dimensions.

The for[illegible] were made oversize by a calculated amount to compensate for the normal shrinkage of the clay during the firing procedure. Since both contractors use different clay types and formulas, blocks and casings cannot be transferred from contractor to contractor.

Storage agreements were entered into between the contractors and Government in which it was agreed that each contractor would be authorized to sell the Government designed forms to any company desiring to use them, either for Government contract, or commercial application.

Utilization of blocks and casings owned by the Government insures that anyone desiring forms of this type may procure them. The usual commercial policy, in the past, has been that if one contractor designs a dipping form, none of the same design will be sold to a competitor.

Measurements of the porcelain forms showed some slight variation from form to form. This was due to the position in which it was placed in the kiln, variation in final temperature reached and duration of firing. However, the variation was no greater than occurs in standard commercial practice. Thus, the porcelain dipping forms fabricated using blocks and casings based on the Government design are considered acceptable.

Trial Dipping of Unsupported Gloves

At the completion of the contracts for the porcelain dipping forms, a quantity of unsupported gloves in one size only were dipped in order to insure that the forms could be utilized on production type application and not only by hand method used in the prototype construction.

A butyl cement of light viscosity was used for dipping trials. Mounting of the forms required a special bracket on the bottom of each

dipping form for the purpose of getting the proper flow of rubber cement over the surface of the special shaped form. Aside from the special bracket, there were no other dipping problems.

IX. Discussion

At the beginning of the design of the "hands" and resulting dipping forms there was some doubt as to the feasibility of dipping either supported or unsupported gloves over forms of this shape due to the relatively sharp edges, extreme curve of the fingers, the limited spaces between fingers, and position of the thumb, in comparison to present commercial dipping forms. However, this all had to be proven in actual dipping operations.

During dipping of the quantities ordered, it was found that no abnormal types of dipping defects occurred. The defects consisted mostly of webbing between the fingers which was eliminated by blowing a light stream of air against the webs during the drip-off process.

Some operator instruction was required prior to successful dipping. In general, all the normal controls and procedures which apply to the production dipping of new designs of commercial supported gloves also apply to gloves of this new design.

X. Conclusions

a. It has been found that the measurements of the experimental master model hand forms can be used as the basis of design and measurements of all types of dipped handwear developed by the Quartermaster Corps for use by Army personnel.

b. Fabric lined vinyl coated gloves can be manufactured over dipping forms based on the experimental master model hands which meet the size and design requirements of the Army.

c. Unsupported rubber, or rubber type gloves can be manufactured over porcelain dipping forms designed in accordance with Master Model dipping forms designed and developed by the Quartermaster Corps.

d. These forms are available to the glove dipping industry for either military or commercial application.

XI. Future Plans

The next logical step requires an analysis of the functional performance needed by the other Departments of the Department of Defense in supported and unsupported dipped handwear with a view to the development of a minimum number of types to meet all needs and achievements of interdepartmental standardization of both the various gloves themselves

and of glove sizing. This has already been accomplished for Guided Missile Fuel Handling with the Departments of the Air Force and Navy. A further phase should include other Government agency users of such gloves.

The final portion of this series of developments should consist of determining the application of the basic reference hands to the development of cut and sewn leather and fabric handwear and possible wholly new methods of glove fabrication, such as techniques for producing permeable gloves by dipping, by electrostatic deposition of fibers onto hand forms by chemical, thermal, or mechanical shrinkage of cut and sewn handwear to shape, etc.

The design and development of natural hand leather gloves will be discussed under a separate report.

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TABLE I

Dimensions Derived from Manumetric Studies

Hand Length
(inches)

	Air Force		Army	
Percentile (%)	Flying Personnel	Basic Trainees	Separatees	D. & E.
1	6.7	6.7	6.74	
5	6.9	6.9	6.98	
10	7.1	7.1	7.10	
25	7.3	7.3	7.32	
50	7.5	7.5	7.68	
75	7.7	7.8	7.83	
90	7.9	8.0	8.05	
95	8.0	8.2	8.20	
99	8.3	8.5	8.47	
Range:	5.87 - 8.74	6.42 - 8.74	5.8 - 9.2	6.3 - 8.9
Mean:	7.49	7.54	7.58	7.54
S.D.:	.34	.38	.36	.36
Number:	4063	3328	24,500	5295
Age (Yrs):	27.87	18.94	24.28	20.45

TABLE II

Dimensions Derived from Manumetric Studies

Finger Length Expressed as a Percentage of Hand Length
(inches)

Percentile (%)	Index Finger	Middle Finger	Ring Finger	Little Finger
1	32.42	39.92	37.06	24.97
5	34.21	40.97	37.83	27.03
10	34.87	41.36	38.48	27.80
25	36.03	42.26	39.62	28.91
50	37.15	43.24	40.79	30.16
75	38.62	44.36	41.85	31.35
90	39.93	45.41	42.95	32.49
95	40.65	45.82	43.63	33.04
99	42.03	46.64	44.82	34.27
Mean:	37.28	43.29	40.76	30.10
S.D.:	1.96	1.51	1.68	1.83

TABLE III

Dimensions Derived from Manumetric Studies

Hand Breadth (inches)

	Air Force		Army	
Percentile (%)	Flying Personnel	Basic Trainees	Separatees	D. & E.
1	3.12	3.04		
5	3.22	3.15		
10	3.28	3.21	3.15	
25	3.36	3.32	3.28	
50	3.49	3.45	3.41	
75	3.59	3.55	3.55	
90	3.69	3.66	3.64	
95	3.74	3.73		
99	3.86	3.88		
Range:	2.99 - 4.09	2.76 - 4.13	2.66 - 4.23	2.76 - 4.13
Mean:	3.48	3.44	3.415	3.39
S.D.:	.16	.18	.19	.20

TABLE IV

Dimensions Derived from Manumetric Studies

Wrist Circumference (inches)

	Air Force		Army
Percentile (%)	Flying Personnel	Basic Trainees	Separatees
1	6.0	6.1	
5	6.3	6.3	
10	6.4	6.4	6.2
25	6.6	6.6	6.4
50	6.8	6.9	6.7
75	7.1	7.2	7.0
90	7.4	7.4	7.2
95	7.5	7.6	
99	7.8	7.8	
Range:	3.94 - 8.27	5.5 - 9.1	5.22 - 8.36
Mean:	6.85	6.87	6.70
S.D.:	.40	.40	.40

TABLE V

Dimensions Derived from Manumetric Studies

Hand Thickness at Metacarpale III
(inches)

Percentile (%)	Air Force Flying Personnel	Basic Trainees
1	1.00	.98
5	1.05	1.05
10	1.08	1.09
25	1.13	1.14
50	1.17	1.20
75	1.21	1.26
90	1.25	1.31
95	1.28	1.35
99	1.35	1.43
Range:	.75 - 1.54	.79 - 1.57
Mean:	1.17	1.19
S.D.:	.07	.09

TABLE VI

Dimensions Derived from Manumetric Studies

Fist Circumference (inches)

	Air Force	
Percentile (%)	Flying Personnel	Basic Trainees
1	10.2	9.84
5	10.7	10.39
10	10.9	10.59
25	11.2	10.94
50	11.6	11.30
75	11.9	11.67
90	12.3	12.09
95	12.4	12.28
99	12.8	12.72
Range:	7.09 - 13.39	7.5 - 15.3
Mean:	11.56	11.31
S.D.:	.57	.63

TABLE VII

Dimensions Derived from Manumetric Studies

Palm Length (inches)

Percentile (%)	Air Force Flying Personnel	Basic Trainees
1	3.77	3.69
5	3.89	3.92
10	3.97	4.00
25	4.10	4.13
50	4.24	4.29
75	4.38	4.45
90	4.52	4.60
95	4.60	4.71
99	4.74	4.91
Range:	3.39 - 5.04	3.23 - 5.28
Mean:	4.24	4.29
S.D.:	.21	.25

TABLE VIII

Dimensions Derived from Manumetric Studies

Palm Circumference
(inches)

	Air Force
Percentile (%)	**Basic Trainees**
1	7.28
5	7.67
10	7.84
25	8.12
50	8.42
75	8.74
90	9.02
95	9.23
99	10.02
Range:	4.7 - 12.6
Mean:	8.46
S.D.:	.58

TABLE IX

Dimensions Derived from Manumetric Studies

Hand Breadth at Thumb
(inches)

	Air Force	
Percentile (%)	Flying Personnel	Basic Trainees
1	3.59	3.51
5	3.73	3.71
10	3.80	3.80
25	3.93	3.95
50	4.08	4.12
75	4.21	4.29
90	4.35	4.45
95	4.42	4.54
99	4.57	4.72
Range:	3.23 - 4.76	3.2 - 5.0
Mean:	4.07	4.12
S.D.:	.21	.25

TABLE X

Dimensions Derived from Manumetric Studies

	Grip Diameter (Inside) (inches)	Grip Diameter (Outside) (inches)
	Air Force	
Percentile (%)	Flying Personnel	Flying Personnel
1	1.52	3.58
5	1.62	3.72
10	1.67	3.81
25	1.75	3.94
50	1.83	4.09
75	1.92	4.24
90	2.00	4.37
95	2.05	4.44
99	2.16	4.57
Range:	1.37 - 2.63	3.15 - 4.72
Mean:	1.90	4.09
S.D.:	.14	.21

TABLE XI

Dimensions Derived from Manumetric Studies

Percentile (%)	First Phalanx III Length (inches) Air Force Flying Personnel	Finger Diameter III* (inches) Flying Personnel
1	2.40	.77
5	2.49	.79
10	2.52	.80
25	2.59	.82
50	2.67	.85
75	2.74	.89
90	2.82	.91
95	2.85	.93
99	2.95	.96
Range:	2.21 - 3.07	.75 - 1.00
Mean:	2.67	.86
S.D.:	.12	.05

* Maximum diameter of middle finger

TABLE XII

Dimensions Used for Fabrication of Synthetic Hands

Position	Size Small	Per-centile Level (%)	Size Medium	Per-centile Level (%)	Size Large	Per-centile Level (%)
Hand length Used only as figuring base	7-13/32	30	7-22/32	75	8-8/32	98
A. Wrist to knuckle	4-13/32		4-22/32		5-1/32	
B. Palm length bent	3-23/32		3-27/32		4-1/32	
C. Breadths at metatarsal, bent (Correction factor 4/32)	3-17/32	30	3-23/32	75	3-30/32	97
D. Thickness at metatarsal II, bent	1-5/32		1-7/32		1-10/32	
E. Thickness at metatarsal III, flat (+ 4/32 correction factor)	1-9/32	30	1-11/32	75	1-14/32	95
F. Thickness at metatarsal V	1-4/32		1-6/32		1-9/32	
G. Palm at metatarsal V	1-16/32		1-18/32		1-24/32	
Fingers						
H. Index, center length	2-16/32	5	2-25/32	30	3-6/32	75
J. Index, outer length	3-20/32		3-29/32		4-10/32	
K123. Index, diameter at each joint	26/32 (K1) 28/32 (K2) 23/32 (K3)		26/32 (K1) 29/32 (K2) 24/32 (K3)		28/32 (K1) 31/32 (K2) 26/32 (K3)	
L. Middle, center length	3-1/32	5	3-9/32	30	3-21/32	75

TABLE XII (CONT'D)

Dimensions Used for Fabrication of Synthetic Hands

Position	Size Small	Percentile Level (%)	Size Medium	Percentile Level (%)	Size Large	Percentile Level (%)
Fingers (Cont'd)						
M. Middle, outer length	4-8/32		4-16/32		4-28/32	
N123. Middle, diameters at each joint	27/32 (N1) 30/32 (N2) 25/32 (N3)	30	28/32 (N1) 31/32 (N2) 26+/32 (N3)	75	30-/32 (N1) 33-/32 (N2) 28/32 (N3)	95
O. Ring, center length	2-26/32	5	3-2/32	30	5-14/32	75
P. Ring, outer length	4-2/32		4-10/32		4-22/32	
Q123. Ring, diameters at each joint	25/32 (Q1) 27/32 (Q2) 23+/32 (Q3)		26/32 (Q1) 28/32 (Q2) 24+/32 (Q3)		28-/32 (Q1) 30-/32 (Q2) 26/32 (Q3)	
R. Fifth, center length	2	5	2-8/32	30	2-19/32	75
S. Fifth, outer length	3-6/32		3-14/32		3-25/32	
T123. Fifth, diameters at each joint	23/32 (T1) 24/32 (T2) 21/32 (T3)		24/32 (T1) 25/32 (T2) 22/32 (T3)		26-/32 (T1) 27-/32 (T2) 24-/32 (T3)	
U. <u>Thumb</u> length outside	2-13/32		2-21/32		3	
V123. Thumb, diameters at each joint	31/32 (V1) 27/32 (V2) 23+/32 (V3)		32/32 (V1) 28/32 (V2) 24+/32 (V3)		34-/32 (V1) 30-/32 (V2) 26/32 (V3)	
W. Palm circumference (+ bend correction of 20/32)	8-26/32	30	9-12/32	75	9-28/32	95
X. Wrist circumference	6-19/32	30	7-3/82	75	7-16/32	95
Y. Bottom to wrist, difference	2-26/32		2-29/32		3-1/32	
Fist circumference (Used for figuring base)	11-10/32	30	11-29/32	75	12-13/32	95

TABLE XIII

Measurements for Size X-Large

Fingers	Position (inches)		
Index	J 4-13/32		
	K1 31/32	K2 35/32	K3 30/32
Middle	M 4-31/32		
	N1 33/32	N2 37/32	N3 33/32
Ring	P 4-25/32		
	Q1 31/32	Q2 34/32	Q3 30/32
Fifth	S 3-28/32		
	T1 29/32	T2 31/32	T3 28/32
Thumb	U 3-3/32		
	V1 37/32	V2 34/32	V3 30/32

Other measurements about 3/32 inches greater than size large except C which is 12/32 inches larger to accommodate thicker fingers.